Claims

1. A method for estimating a bearing from an antenna situated at a cellsite to a mobile station in a radio telecommunications system, said antenna comprising a plurality of antenna elements for receiving signals transmitted by said mobile station, said received signals having a frequency including a frequency offset, being a Doppler frequency offset due to motion of said mobile station and/or a carrier frequency offset, and having a phase and an amplitude at each antenna element dependent on said bearing and on said frequency, comprising the steps of;

(A): during each of a plurality of successive sampling times obtaining a set of signal samples, by sampling said signal received at each said antenna element during a dwell time shorter than said sampling time, such that not all of said received signals are sampled simultaneously;

(B): estimating said phase and said amplitude of each said signal sample to obtain a corresponding complex phasor;

(C): estimating said frequency offset using two or more of said phasors derived from signal samples successively received at one of said antenna elements;

(D): applying a phase-rotation compensation according to said estimate of said frequency offset to said phasors corresponding to each of said antenna elements to obtain compensated phasors; and

(E): estimating said bearing using a set of said compensated phasors corresponding to at least one set of signal samples.

2. A method according to claim 1, in which said dwell time at each said antenna element is of equal duration.

3. A method according to claim 1, in which step (B) includes the step of correlating each said signal sample with a predetermined reference signal.

4 A method according to claim 1, in which in step (C) said frequency offset is estimated by carrying out a Fourier Transform.

5. A method according to claim 1, in which in step (A) after said plurality of successive sampling times a corresponding plurality of said sets of signal samples is obtained, step (B) is performed on each said set of signal samples, step (D) is performed on each corresponding set of phasors derived therefrom, and step (E) includes the steps of carrying out a spatial Fourier Transform on each said set of compensated phasors and incoherently summing the results of each said spatial Fourier Transform to estimate said bearing.

6. A method for estimating a bearing from an antenna situated at a cellsite to a mobile station in a radio telecommunications system, said antenna comprising a plurality of antenna elements for receiving signals transmitted by said mobile station, said received signals having a frequency spectrum, and a phase and an amplitude at each antenna element dependent on said bearing and said frequency spectrum, comprising the steps of;

(A): during each of a plurality of successive sampling times obtaining a set of signal samples, by sampling said signal received at each said antenna element during a dwell time shorter than said sampling time such that not all of said received signals are sampled simultaneously, in order to obtain an array of said signal samples, each row of said array comprising one of said sets of signal samples and each column of said array

containing a plurality of said signal samples from one of said antenna elements;

(B): estimating said phase and said amplitude of each said signal sample to generate a corresponding complex phasor so as to obtain a corresponding array of said phasors;

(C): performing a Fourier transform on each column of said array of phasors, each said Fourier transform having an output quantized into frequency components to obtain a frequency-component phasor representing the contribution of each frequency component to said phase and said amplitude of said signal samples at said corresponding antenna element during said plurality of sampling times;

(D): compensating each said frequency-component phasor according to a frequency of said corresponding frequency component; and

(E): estimating said bearing on the basis of said compensated phasors.

7. A method according to claim 6, in which in step (A) said signal samples in each said set of signal samples are sampled sequentially during dwell times substantially equal to said sampling time divided by said number in said plurality of antenna elements.

8. A method according to claim 6, in which in step (B) said phase and said amplitude of each said signal sample are estimated by correlation with a reference signal.

9. A method according to claim 6, in which in step (E) said bearing is estimated by performing a spatial Fourier transform on said compensated phasors corresponding to each said frequency component to obtain a spectrum of energy (or intensity) versus bearing corresponding to each

said frequency component and incoherently adding said spectra.

10. A method according to claim 6, in which in step (D) each said frequency-component phasor is compensated to correct phase rotation arising from a frequency difference between said frequency of said frequency-component phasor and said reference signal, and from a delay between sampling said signal samples at each said antenna element.

11. A method according to claim 6, in which said frequency spectrum includes a Doppler frequency spread due to motion of said mobile station.

12. A method for calibrating a receiver circuit coupled to a direction-finding antenna in a radio telecommunications system, said receiver circuit including signal-phase-sensitive direction-finding signal-processing equipment, comprising the steps of;

injecting a calibration signal into said receiver chain in the proximity of said antenna;

processing said calibration signal in said receiver circuit to generate an output; and

comparing said output with a predetermined reference synchronised with said calibration signal to assess said calibration of said receiver circuit.

13. A method for calibrating a direction-finding antenna and a receiver circuit to which it is coupled in a radio telecommunications system, said receiver circuit including signal-phase-sensitive direction-finding signal-processing equipment, comprising the step of;

providing a near-field calibration source within a coverage area of said antenna;

transmitting a calibration signal from said source for reception by said antenna;

processing said received calibration signal in said receiver circuit to generate an output; and

comparing said output with a predetermined reference synchronised with said calibration signal to assess calibration of said antenna and said receiver circuit.

14. A method for calibrating a direction-finding antenna coupled to a receiver circuit situated at a cell site of a cellular radio telecommunications system, a communications transceiver for communicating with mobile stations of said system also being situated at said cell site, comprising the steps of;

providing a radio transceiver beacon at a predetermined, known position at a known bearing and/or distance from said cell site;

controlling said communications transceiver to set up a call with said beacon during which said beacon transmits signals to said cell site;

receiving said signals at said direction-finding antenna; and

processing said received signals in said receiver circuit to estimate a bearing from said cell site to said beacon and/or a distance between said cell site and said beacon and comparing said estimate or estimates with said known bearing and/or distance.

15. A method according to claim 14, in which said step of providing said beacon comprises providing a mobile station compatible with said telecommunications system.

16. A method according to claim 14, in which said beacon is provided at said position such that it can communicate with more than one cell site in order to calibrate direction finding antennas and receiver circuits at each said cell site.

17. A method for calibrating a direction finding antenna situated at a first cell site of a cellular radio telecommunications system, comprising the steps of;

providing a transmitter beacon at a second cell site adjacent to said first cell site;

transmitting a signal from said beacon;

receiving said signal at said direction-finding antenna; and

processing said received signal using receiver circuitry coupled to said direction finding antenna to estimate a bearing from said first cell site to said second cell site, comparing said estimate with a known bearing from said first cell site to said second cell site, and calibrating said direction finding antenna and/or said receiver circuitry accordingly.

18. A method according to claim 17, in which said radio telecommunications system is a CDMA (code division multiple access) system and said signal transmitted by said beacon is a narrowband signal within or near the allocated CDMA bandwidth.

19. A method according to claim 17, in which said signal transmitted by said beacon can be used to calibrate direction finding antennas at a plurality of adjacent cell sites.

20. A method for calibrating a direction finding antenna and/or associated receiver circuitry at a cell site of a radio telecommunications system, comprising the step of selecting one or more of the calibration methods of injecting a calibration signal into said circuitry near said antenna, providing a near-field calibration source, providing a radio transceiver beacon and providing a radio transmitter beacon at an adjacent cell site.

21. An apparatus for estimating a bearing from a cellsite to a mobile station in a radio telecommunications system, comprising;

an antenna situated at said cellsite and comprising a plurality of antenna elements for receiving signals transmitted by said mobile station, said received signals having a frequency including a Doppler frequency offset due to motion of said mobile station and/or a carrier frequency offset, and a relative phase and an amplitude at each said antenna element dependent on said bearing and on said frequency;

a receiver circuit; and

a switch for, during each of a plurality of successive sampling times, sequentially coupling each of said plurality of antenna elements to said receiver circuit to enable sampling by said receiver circuit of signals received by each said antenna element from said mobile station;

and said receiver circuit comprising;

a signal sampler for sampling said signals from said antenna elements;

a phase and amplitude estimator for estimating a phasor representing said phase and said amplitude of each said signal sample;

a frequency offset estimator for estimating said frequency offset using two or more of said phasors derived from one of said antenna elements in successive sampling times;

a phase compensator for compensating said phasors according to said frequency offset; and

a bearing estimator for estimating said bearing using said compensated phasors.

22. An apparatus according to claim 21, in which said phase and amplitude estimator correlates each of said signal samples with a reference signal to generate said phasors.

23. An apparatus according to claim 21, in which said frequency offset estimator estimates said frequency offset by performing a Fourier Transform.

24. An apparatus according to claim 21, in which said bearing estimator estimates said bearing by performing a spatial Fourier transform on one or more sets of compensated phasors, each said set containing one said compensated phasor derived from each said antenna element during one of said sampling times.

25. An apparatus for estimating a bearing from a cellsite

to a mobile station in a radio telecommunications system, comprising;

an antenna situated at said cell site and comprising a plurality of antenna elements for receiving signals transmitted by said mobile station, said signals having a frequency spectrum, and having a relative phase and an amplitude at each antenna element dependent on said bearing and said frequency spectrum;

a receiver circuit; and

a switch for coupling each said antenna element to said receiver circuit during each of a plurality of sampling times for sampling of said received signals by said receiver circuit, said received signals on each antenna element not all being sampled simultaneously during each sampling time;

and said receiver circuit comprising;

a signal sampler for sampling said signals from said antenna elements;

a phase and amplitude estimator for estimating said phase and said amplitude of each said signal sample to generate a corresponding complex phasor in order to obtain an array of said complex phasors, each row of said array comprising a set of one of said complex phasors derived from each said antenna element during one of said sampling times, and each column of said array containing a plurality of said complex phasors derived from one said antenna element during successive sampling times;

a frequency spectrum analyser for performing a Fourier transform on each column of said array of complex phasors to estimate a frequency-component phasors representing a contribution by each of a plurality of frequency components of said frequency spectrum to said phase of said received signal at each antenna

a phase compensator for compensating each said frequency-component phasor according to a frequency of said corresponding frequency component; and

a bearing estimator for estimating said bearing on the basis of said compensated frequency-component phasors.

26. An apparatus according to claim 25, in which said phase compensator compensates each frequency-component phasors to correct phase rotation arising from a frequency

difference between said frequency component and said reference signal, and from a delay between sampling said signal samples at each said antenna element.

27. An apparatus according to claim 25, in which said bearing estimator estimates said bearing by performing a spatial Fourier transform on said compensated frequency-component phasors corresponding to each said frequency component to obtain a spectrum of energy (or intensity) versus bearing for each said frequency component and incoherently adding said spectra obtained for all of said frequency components.

28. An apparatus for calibrating a receiver circuit coupled to a direction finding antenna in a radio telecommunications system, said receiver circuit including phase-sensitive direction-finding signal processing equipment, comprising;

a calibration signal generator for generating a calibration signal;

a signal injector for injecting said calibration signal into said receiver circuit near said antenna so that said receiver circuit can process said calibration signal to generate an output; and

a comparator for comparing said output with a predetermined reference synchronised with said calibration signal to assess calibration of said receiver circuit.

29. An apparatus for calibrating a direction finding antenna and a receiver circuit coupled thereto in a radio telecommunications system, said receiver circuit including phase-sensitive direction-finding signal processing equipment, comprising;

a support for said antenna;

a near-field calibration source mounted on a calibration source support extending from said antenna support;

a calibration signal generator coupled to said calibration source for transmitting a calibration signal from said calibration source for reception by said antenna and processing by said receiver circuit to generate an output; and

a comparator for comparing said output with a reference synchronised with said calibration signal to assess calibration of said antenna and said receiver circuit.

30. An apparatus for calibrating a direction finding antenna at a cell site of a cellular radio telecommunications system, a transceiver for communicating with mobile stations also being situated at said cell site, comprising;

a radio transceiver beacon situated at a predetermined location at a known bearing and/or distance from said cell site;

a controller at said cell site for controlling said transceiver to set up a call with said beacon during which said beacon transmits signals to said cell site;

a receiver circuit coupled to said direction finding antenna for processing said transmitted signals as received at said direction finding antenna and for estimating a bearing from said cell site to said beacon and/or a distance from said cell site to said beacon; and

a comparator for comparing said estimated bearing and/or distance with said known bearing and/or distance.

31. A beacon for use in an apparatus as defined in claim 30.

32. A beacon according to claim 31, comprising a mobile station compatible with said telecommunications system.

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33. An apparatus for calibrating a direction finding antenna and/or a receiver circuit coupled thereto situated at a first cell site of a cellular radio telecommunications system, comprising;

a transmitter beacon situated at a second cell site adjacent to said first cell site;

a calibration signal generator coupled to said beacon for causing said beacon to transmit a calibration signal;

said receiver circuit coupled to said direction finding antenna for processing said calibration signal as received by said direction finding antenna to generate an estimated bearing from said first cell site to said second cell site;

a comparator coupled to said receiver circuit for comparing said estimated bearing with a known bearing from said first cell site to said second cell site; and

a calibrator for calibrating said direction finding antenna and/or said receiver circuit according to said comparison.

34. An apparatus according to claim 33, in which said radio telecommunications system is a CDMA system and said calibration signal is a narrowband signal within a guardband of the allocated CDMA bandwidth.

35. A calibration beacon as defined in claim 33.